CD-I13 AAPPS-DPP2019

3rd Asia-Pacific Conference on Plasma Physics, 4-8,11.2019, Hefei, China

Interplay among 3D flows in turbulent plasmas

Yusuke Kosuga
Research Institute for Applied Mechanics
e-mail (speaker): kosuga@riam.kyushu-u.ac.jp

Turbulent plasmas are ubiquitous in many systems, including astrophysical plasmas and fusion plasmas. One interesting feature of turbulent plasmas is, as a consequence of nonlinear interaction, various secondary flows are formed. For example, drift wave turbulence drives secondary flows, such as zonal flows, radial streamers, intrinsic parallel flows, etc. A consequence of the excitation of these flows is that the flow field of interest likely has 3 dimensional feature. Indeed, theoretical and numerical study do confirm the formation of helical 3D flow patterns(Fig.1) [1,2]. Then a question arises that how we quantify these 3D flow patterns. In this direction, the helicity of flow field, $v\cdot\omega$ where v is velocity field and $\omega=\nabla\times v$ is vorticity, is an important candidate. Understanding how helicity arises in turbulent plasmas is an important issue.

A back-of-an envelope calculation indicates that the helicity of turbulent plasmas is likely to be finite. First of all, we note that the Reynolds number of turbulent plasmas is likely to be larger than one, but moderate. Using a simple estimate $Re\sim\tilde{v}l_c/\nu_c\sim v_*\rho_s/\nu_i$, we find that $Re\sim 1-100$ for typical plasmas of interest. For example, in laboratory experiment, the number is $\sim 2-3$. For ITER plasmas, we have typically $\sim 1-100$. These should be contrasted to the Reynolds number of turbulence in nature, e.g. $Re\sim O(10^9)$ for geo-dynamo problem. Then we would expect that for turbulent plasmas with moderate Reynolds number, the contribution from the Magnus force in the identity

$$(v\cdot\omega)^2+(v\times\omega)^2=|v|^2|\omega|^2$$

would be less pronounced and relative contribution from the helicity would be more important. In addition to the moderate Reynolds number, another important feature of turbulent plasmas is that they are 'wavy'. Numerous waves, modes and instabilities with specific wave polarization are excited, and surely we would find a relevant wave polarization which leaves a footprint in helicity. Helicity seems more relevant parameter for turbulent plasmas than for neutral fluid turbulence. Of course these are based on a back-of-envelope estimate and more rigorous analysis is surely required for more firmer basis.

In this work, we formulate helicity dynamics of turbulent plasmas. Drift wave turbulence and parallel velocity gradient (PVG) turbulence are considered as concrete examples. The choice of these turbulence models is because i.) these are relevant for fusion plasmas, ii.) symmetry can be broken in several ways to give rise to finite helicity, and iii.) numerical data is available for detailed comparison. Basic properties of helicity in strongly magnetized plasmas are summarized. Then dynamics of helicity is formulated, with emphasis on the links to relaxation and transport processes. After deriving evolution equation, we diagnose simulation data based on the balance. Dominant processes are identified for developing finite helicity. We also discuss how helicity could be exploited for relevant applications.

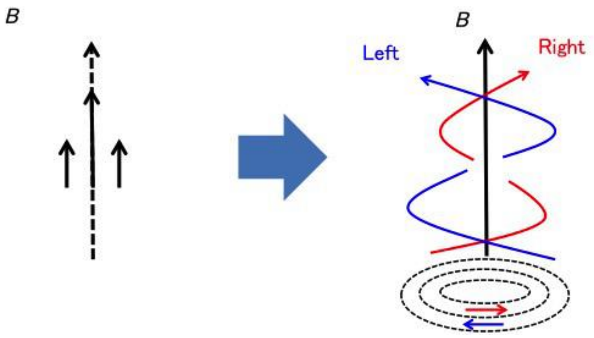

Fig1: Formation of helical flow patterns in PVG turbulence[1]

References

1. Y. Kosuga, S. -I. Itoh, and K. Itoh, Phys. Plasmas 24, 032304 (2017)
2. M. Sasaki, N. Kasuya, K. Itoh, S. Toda, T. Yamada, Y. Kosuga, Y. Nagashima, T. Kobayashi, H. Arakawa, K. Yamasaki, A. Fujisawa, S. Inagaki, and S. -I. Itoh, Phys. Plasmas 24, 112103 (2017)